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Verification of AIRS 2-D Spatial Response Functions and Their Impact On AIRS/MODIS Radiance Comparisons

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AIRS Science Team Meeting

Greenbelt, MD

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Introduction

Atmospheric Infrared Sounder

- **Comparisons of AIRS and MODIS radiances are complicated by both the spectral and spatial differences between the two instruments**
- **This talk concentrates on the spatial differences**
- **We will show that use of the pre-launch measurements of the AIRS spatial response functions have skill in improving AIRS-MODIS radiance comparisons**
- **At the recent SPIE meeting in San Diego we showed results for nadir pixels, comparing some AIRS channels near 11 microns to MODIS Band 31**
- **Today we extend those results to non-nadir pixels and to MODIS band 32**



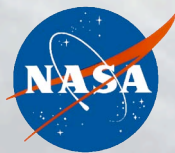
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Outline

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- **Description of the AIRS-MODIS radiance comparison technique used**
- **Review of pre-launch spatial response measurements**
- **Results for MODIS band 31**
- **Results for MODIS band 32**
- **Additional checks**
- **Conclusions**



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Basic Approach

- The primary assumption of this analysis is that each AIRS scene can be considered to be a convolution of an Aqua MODIS scene with the AIRS spatial response function, with the result sampled at AIRS resolution
- Aqua MODIS
 - *Flies on the same platform as AIRS*
 - *Is also a cross-track scanner, so it has very similar ground coverage*
 - It has about 14 times better spatial resolution than AIRS



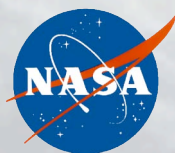
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Description of the Analysis

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- For each AIRS pixel, find a corresponding MODIS radiance using three different methods
 - $R_{AIRS} = R_{MODIS \text{ nearest neighbor}}$
 - $R_{AIRS} = R_{21 \times 21 \text{ mean}}$
 - $R_{AIRS} = R_{\text{weighted sum}}$
- For all three methods the MODIS data were first resampled so that one MODIS pixel fell exactly on the nominal location of the AIRS pixel
- At the end, the AIRS and MODIS radiances were converted to brightness temperatures and the difference (AIRS-MODIS) was plotted for each method

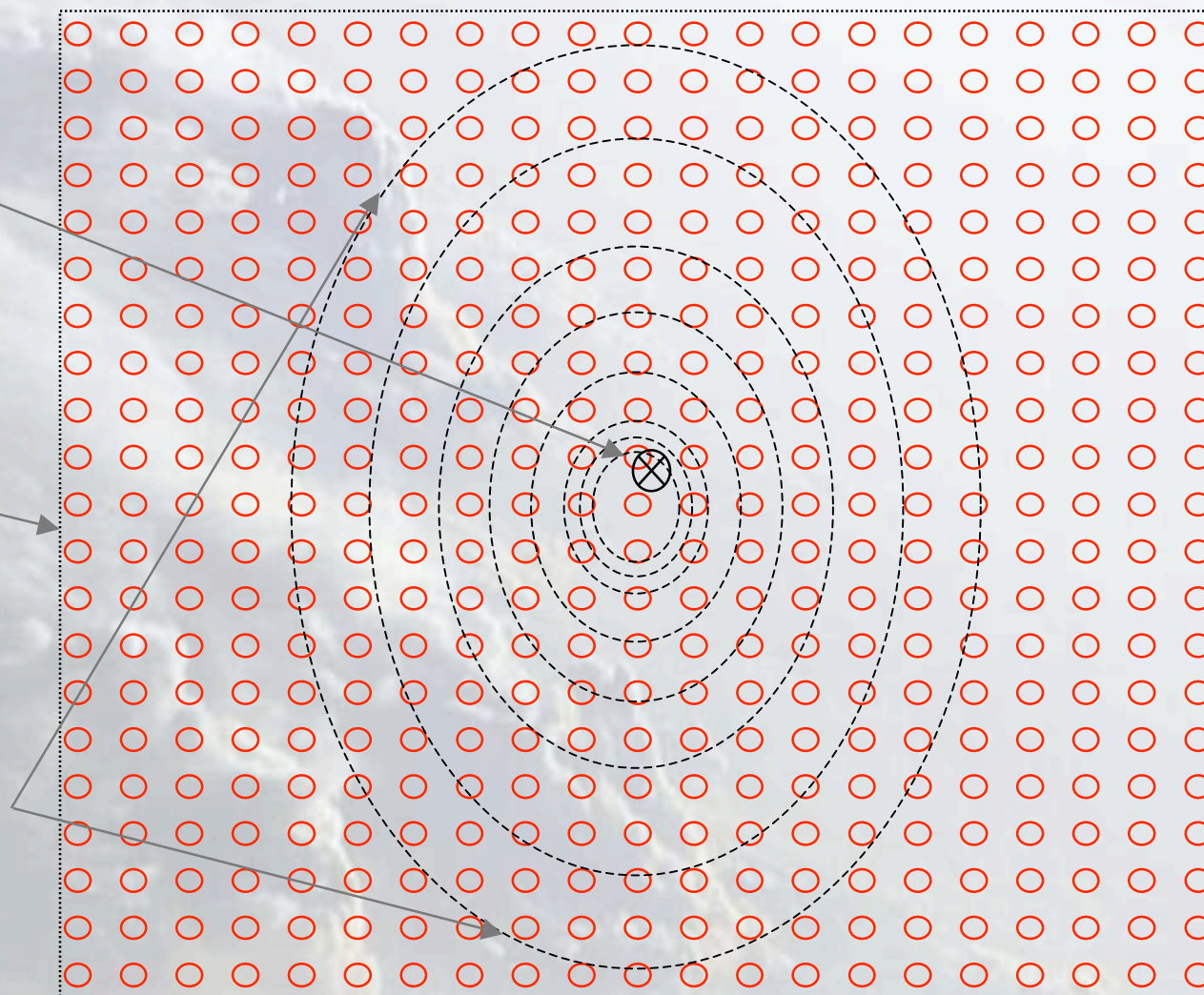


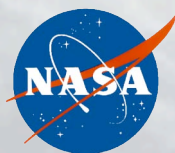
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Three Techniques

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- **Nearest neighbor**
- **21 x 21 average**
- **Sum weighted by spatial response**

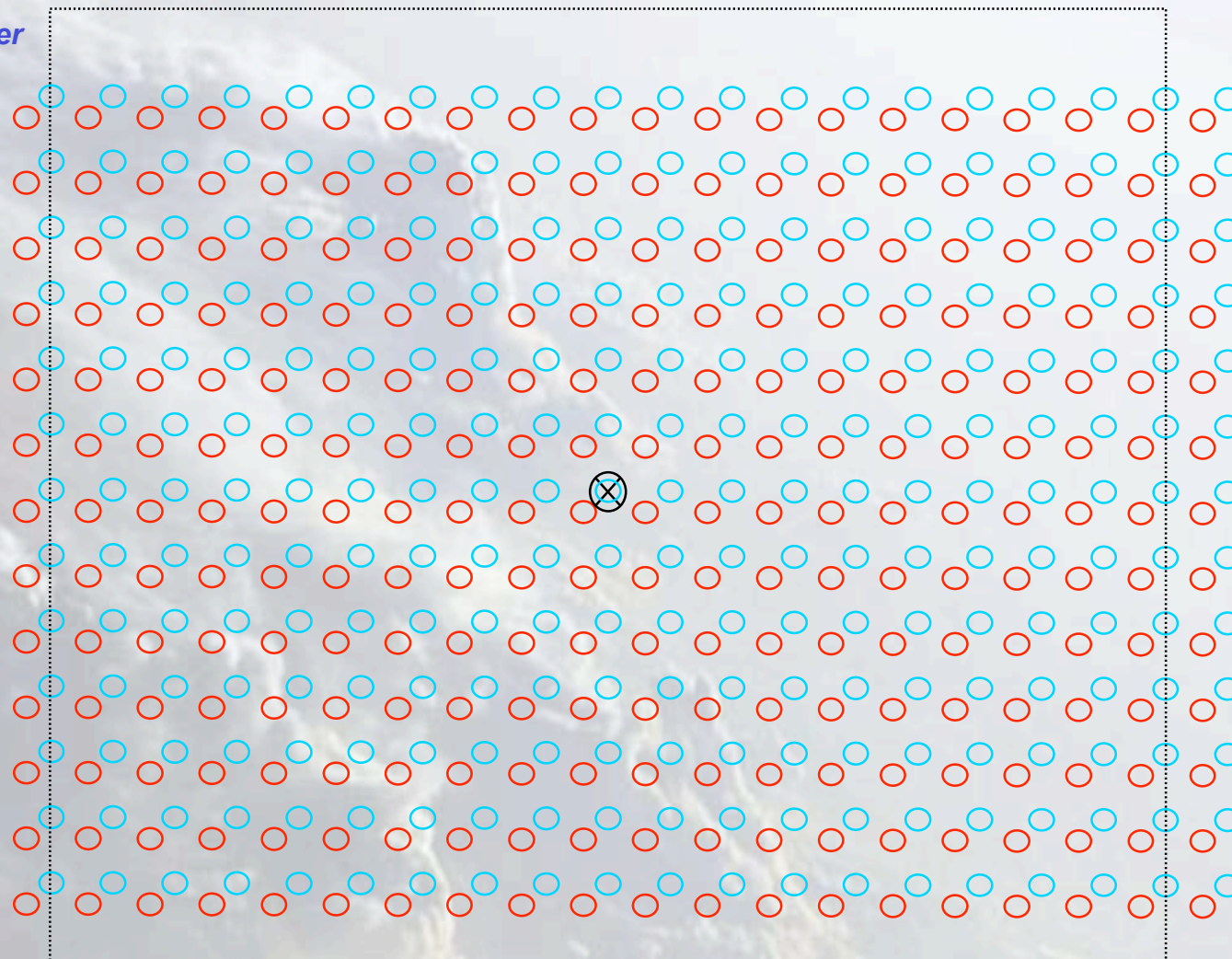




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MODIS Resampling (Conceptual)

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O = original MODIS

O = Resampled MODIS

X = AIRS center

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Sept. 26-29, 2006, Greenbelt, Maryland

AIRS Spatial Response



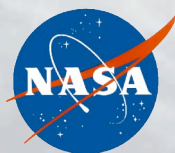
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Pre-Launch Measurements

- A spatial collimator system was used to direct a point-source beam at programmable angles into the AIRS sensor assembly (no scan mirror present)
- Measurements were made on a 39x39 grid of points centered on the nominal boresight
- Spacing between points in both directions was 0.04 degrees for total coverage of a square 1.52 degrees on a side



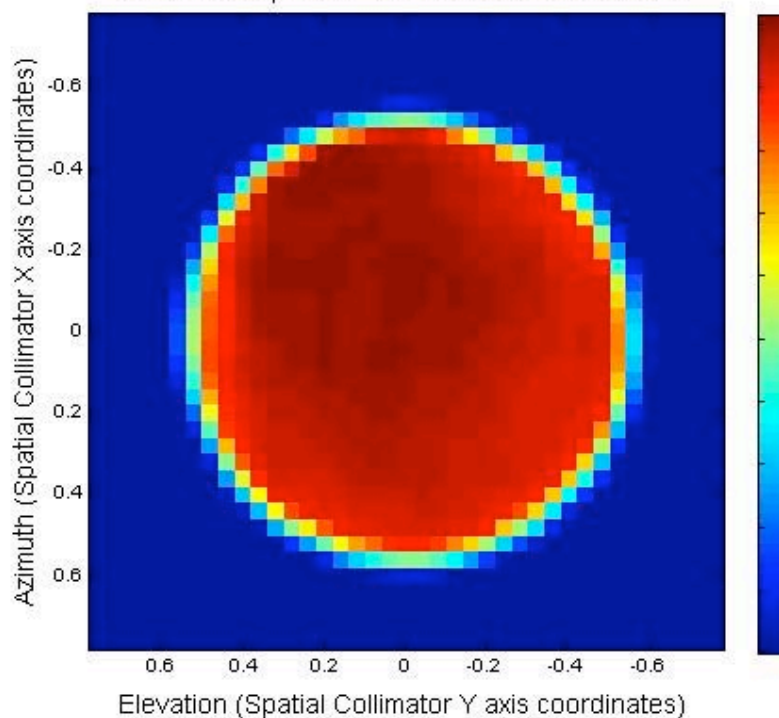
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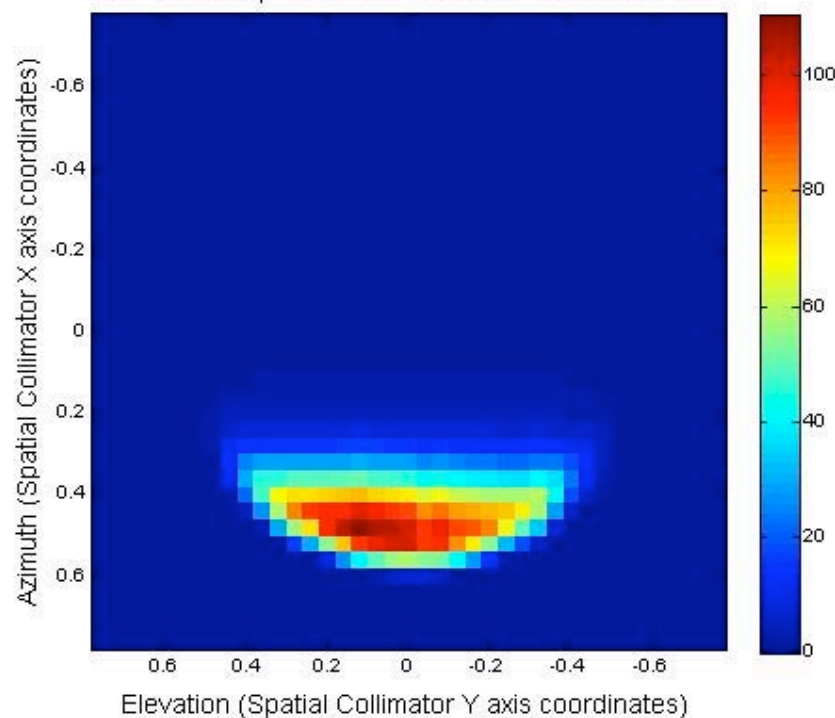
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Sample Raw Spatial Response Functions

Raw AIRS tophat for PGE channel 2373 LMID 5



Raw AIRS tophat for PGE channel 2263 LMID 115



- **Normal AIRS spatial response function at the time of the testing**

Extremely asymmetrical example
Due to shadowing of a detector
near the end of an array



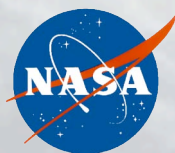
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In-Flight Spatial Response

- The raw response functions are not immediately applicable to flight data
- After testing, a field stop was added which limited the spatial response to 0.6 degrees in the in-scan direction
- The presence of the scan mirror introduces an additional reflection into the system
- As the scan mirror rotates, so does the spatial response
- The AIRS scanner is NOT a stepper, but is in continuous motion—thus the actual response is smeared in the in-scan direction
- The smearing improves the channel-to-channel uniformity of the spatial response, but does not eliminate all variability



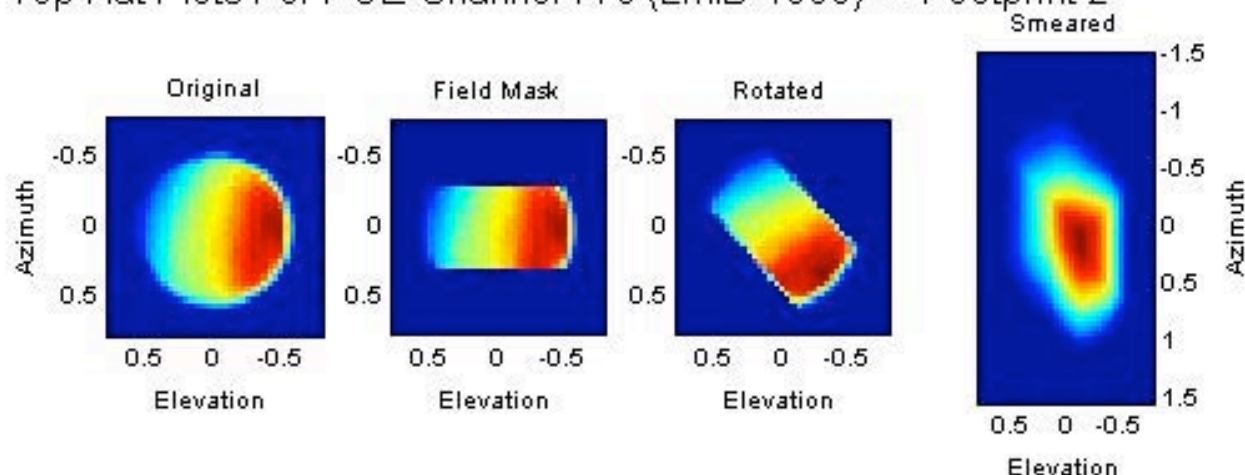
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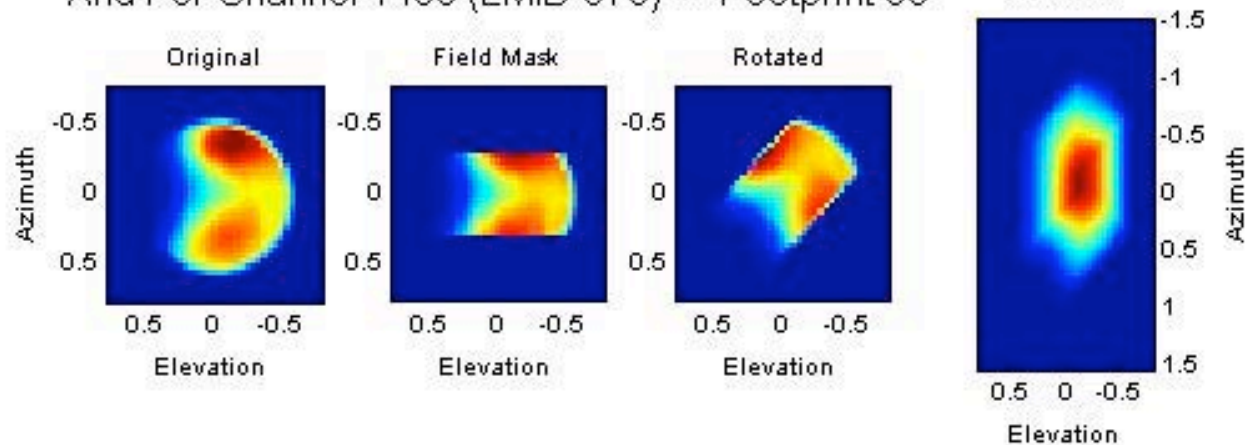
Processing Of Pre-Launch Spatial Response Functions

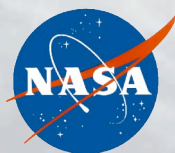
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Top Hat Plots For PGE Channel 773 (LMID 1605) --- Footprint 2



And For Channel 1489 (LMID 679) --- Footprint 89





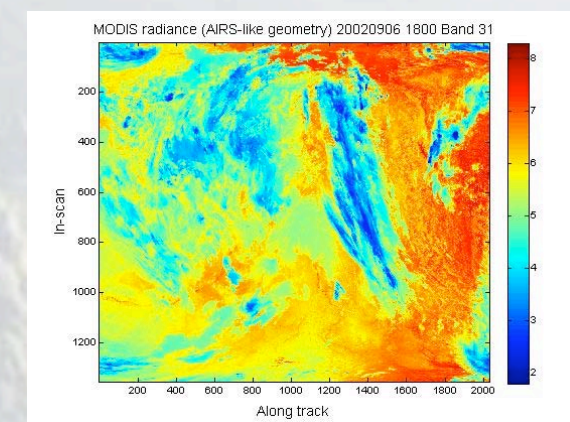
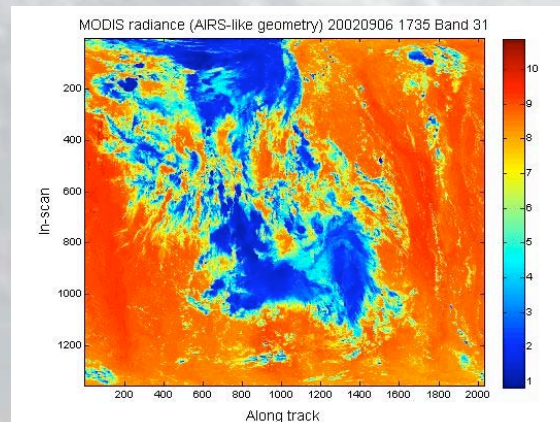
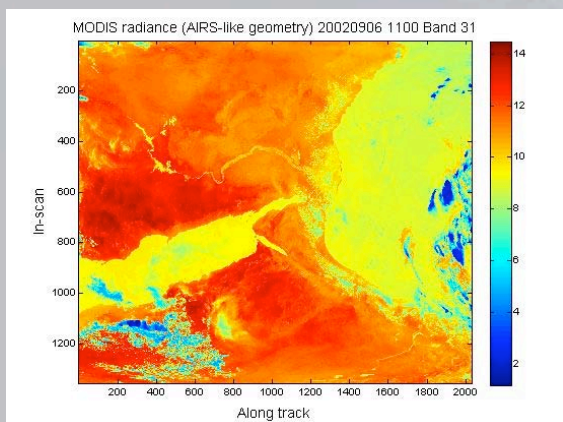
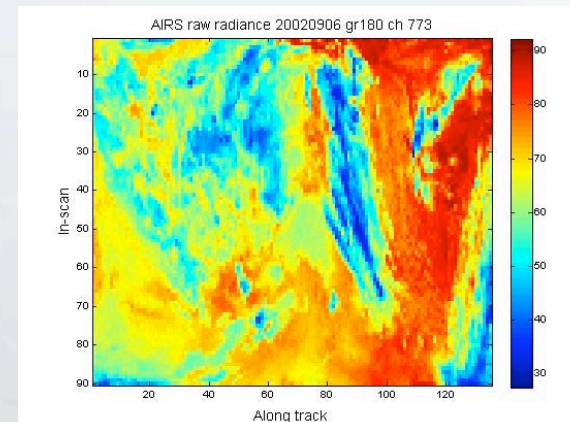
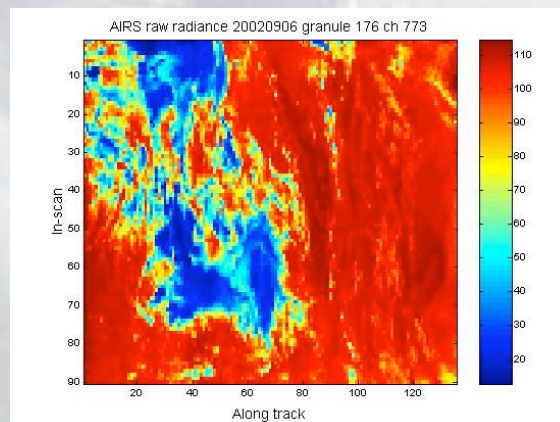
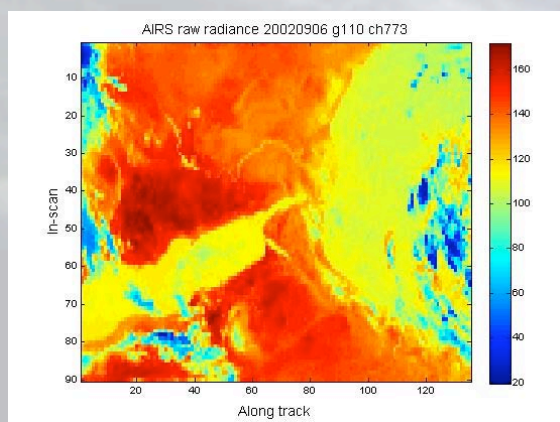
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Data Used

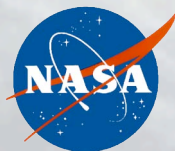
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- 12 AIRS granules from September 6, 2002 (upper row)
- 13 MODIS granules which overlap the AIRS granules (lower)



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AIRS Spatial Response



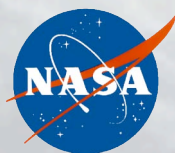
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MODIS Band 31 Comparisons

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- **For AIRS we used the average of four channels near 11 microns:**
 - ***Channel 703*** ***881.399 cm⁻¹***
 - ***Channel 732*** ***891.086 cm⁻¹***
 - ***Channel 760*** ***900.655 cm⁻¹***
 - ***Channel 774*** ***912.656 cm⁻¹***
 - ***These channels are the same as those used by Broberg and Aumann in their SPIE paper on MODIS-AIRS radiance comparisons***
- **For MODIS we used band 31**
- **We used footprints 45 (near nadir), 21, and 70 (about halfway from nadir to opposite ends of the scan line))**

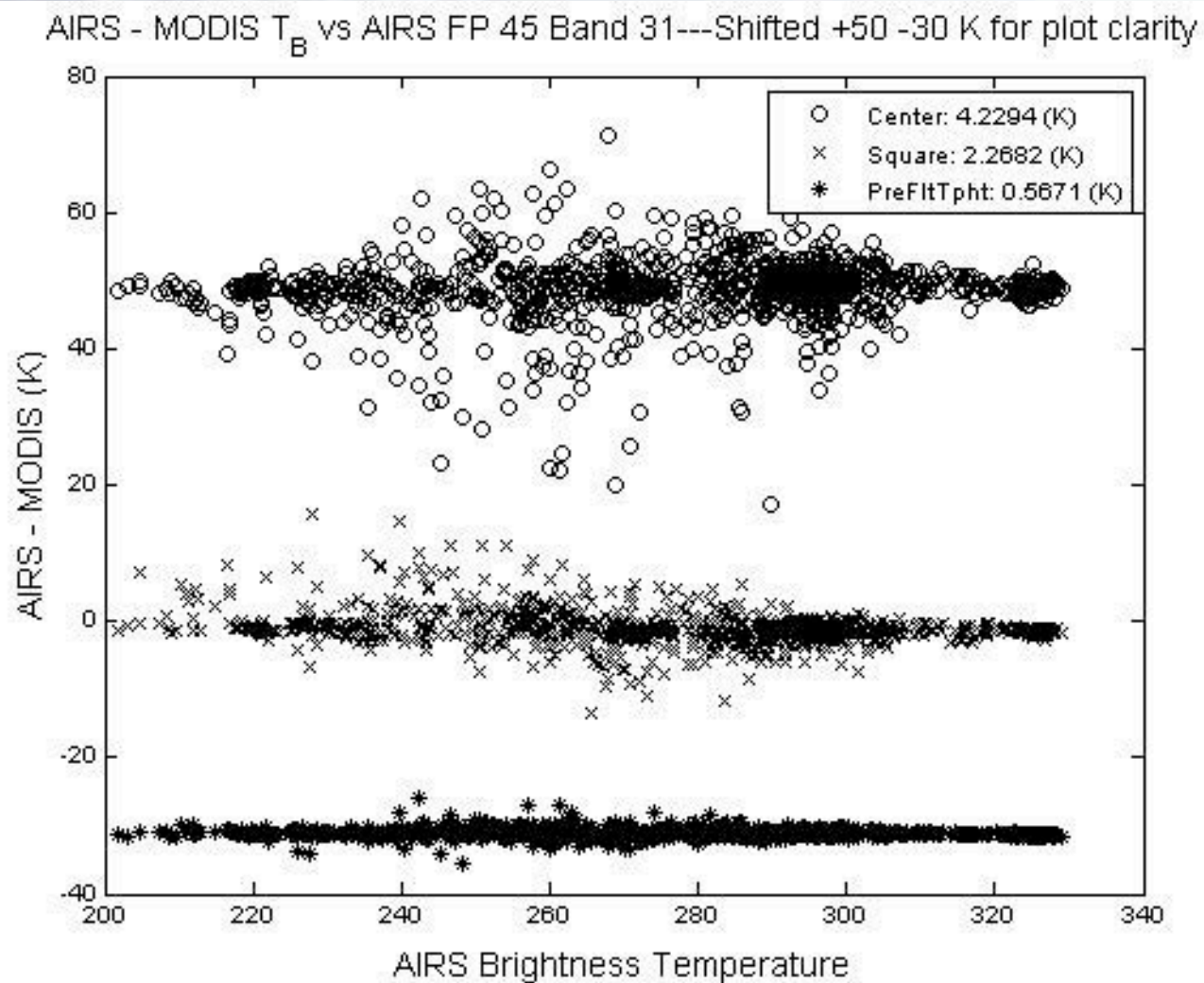


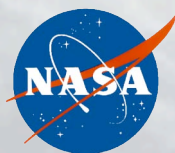
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AIRS - MODIS Band 31 FP45

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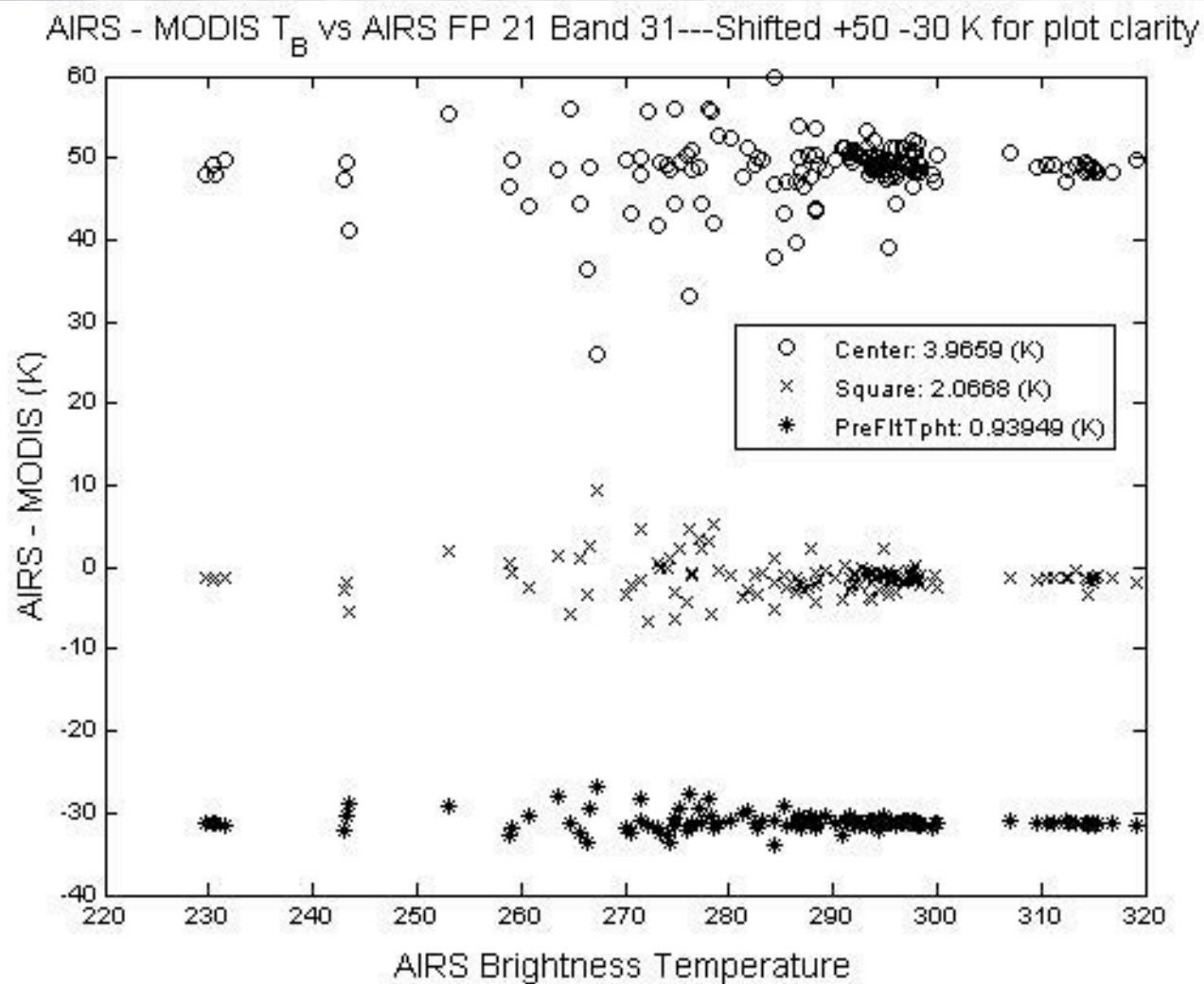


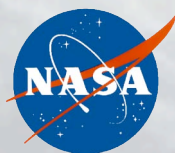
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AIRS - MODIS Band 31 FP21

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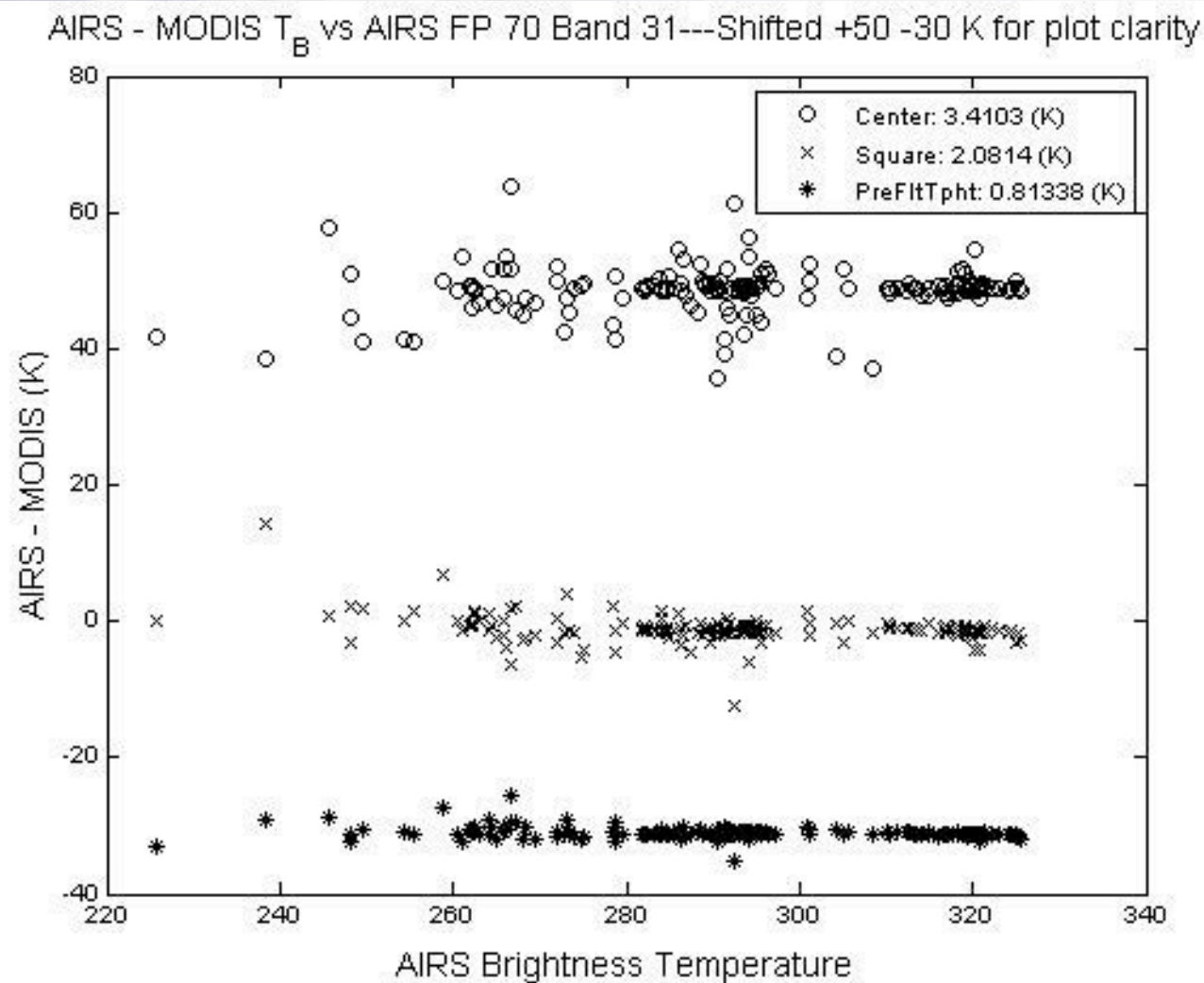


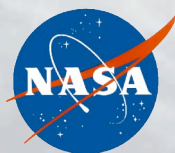
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AIRS - MODIS Band 31 FP70

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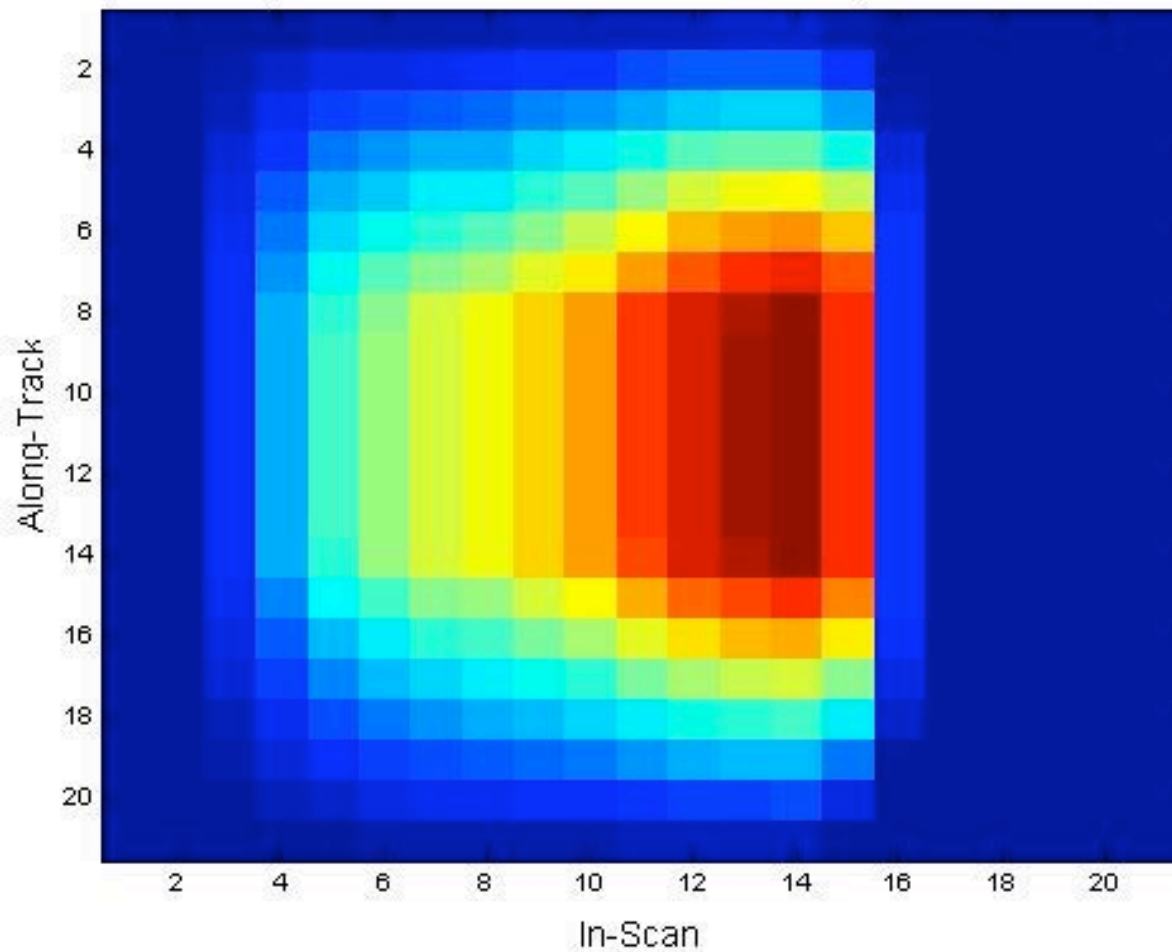
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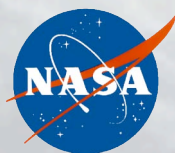
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AIRS Spatial Response at MODIS Resolution, Channel 774 FP45

AIRS Spatial Response For Channel 774 FP70 Resampled To MODIS Resolution





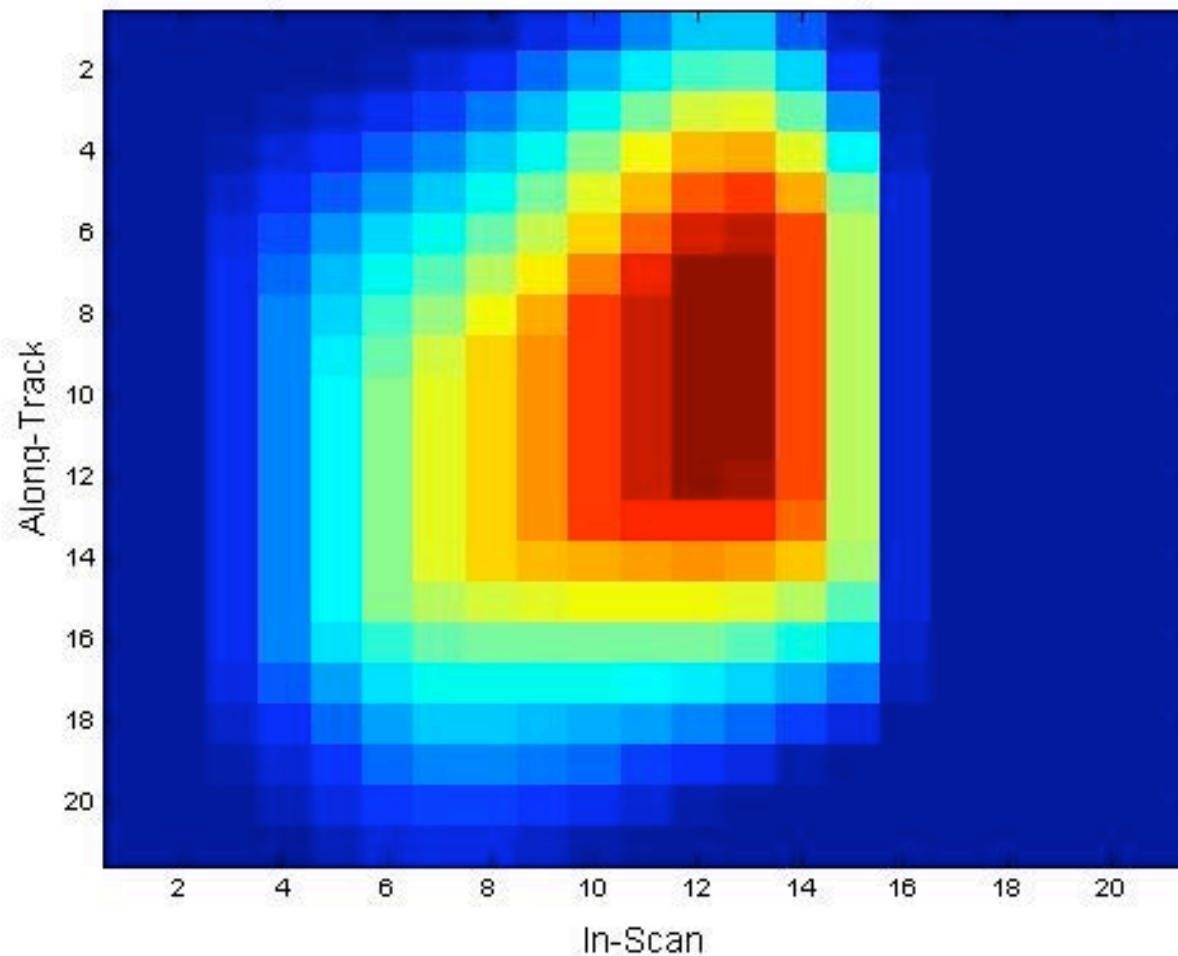
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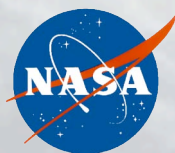
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AIRS Spatial Response at MODIS Resolution, Channel 774 FP21

AIRS Spatial Response For Channel 774 FP21 Resampled To MODIS Resolution





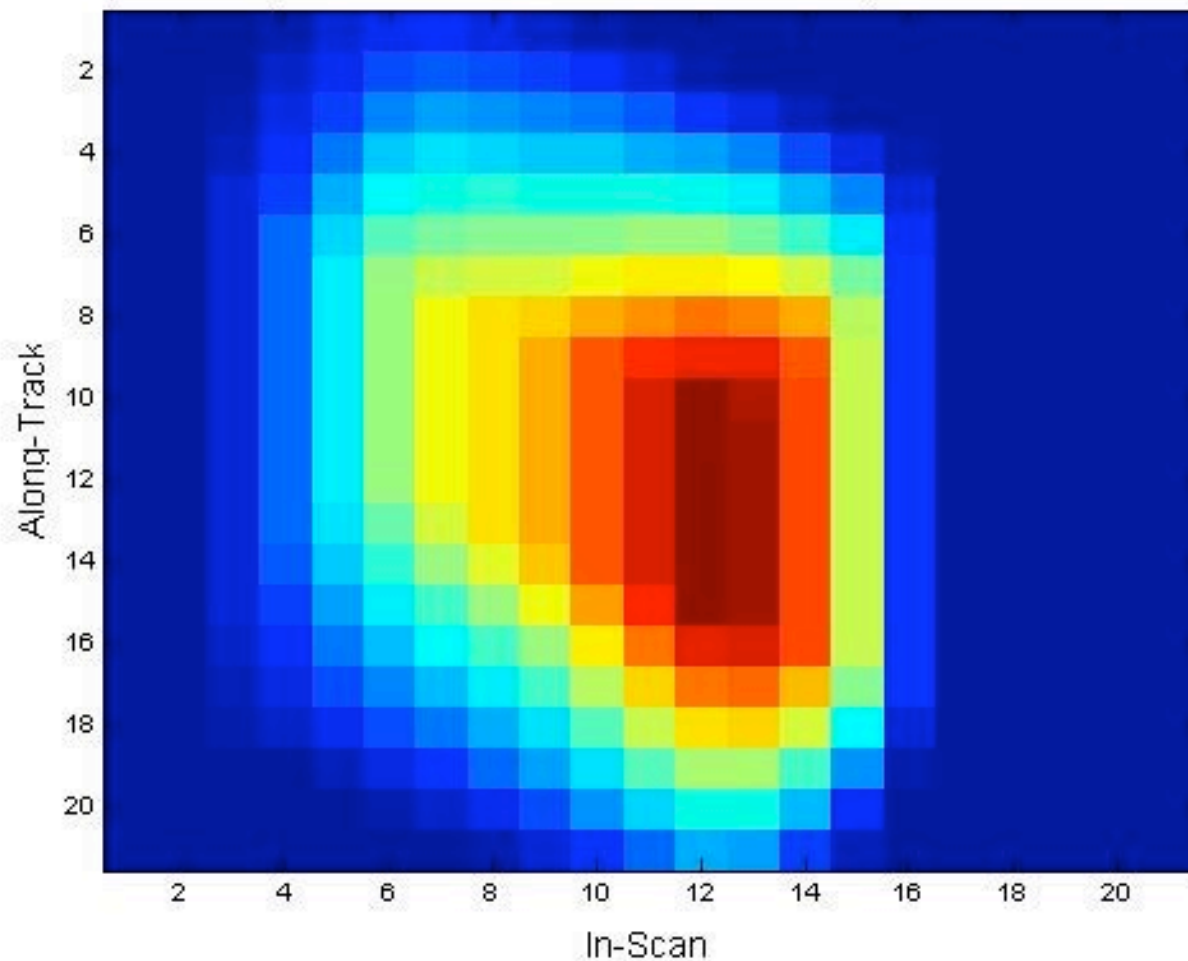
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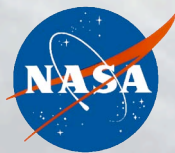
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AIRS Spatial Response at MODIS Resolution, Channel 774 FP70

AIRS Spatial Response For Channel 774 FP70 Resampled To MODIS Resolution





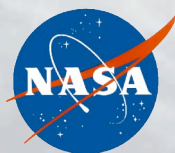
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MODIS Band 32 Comparisons

- **For AIRS we used the weighted average of 32 channels designed to mimic the MODIS band 32 spectral response**
- **For MODIS we used band 32**
- **As before, we used footprints 45 (near nadir), 21, and 70 (about halfway from nadir to opposite ends of the scan line)**

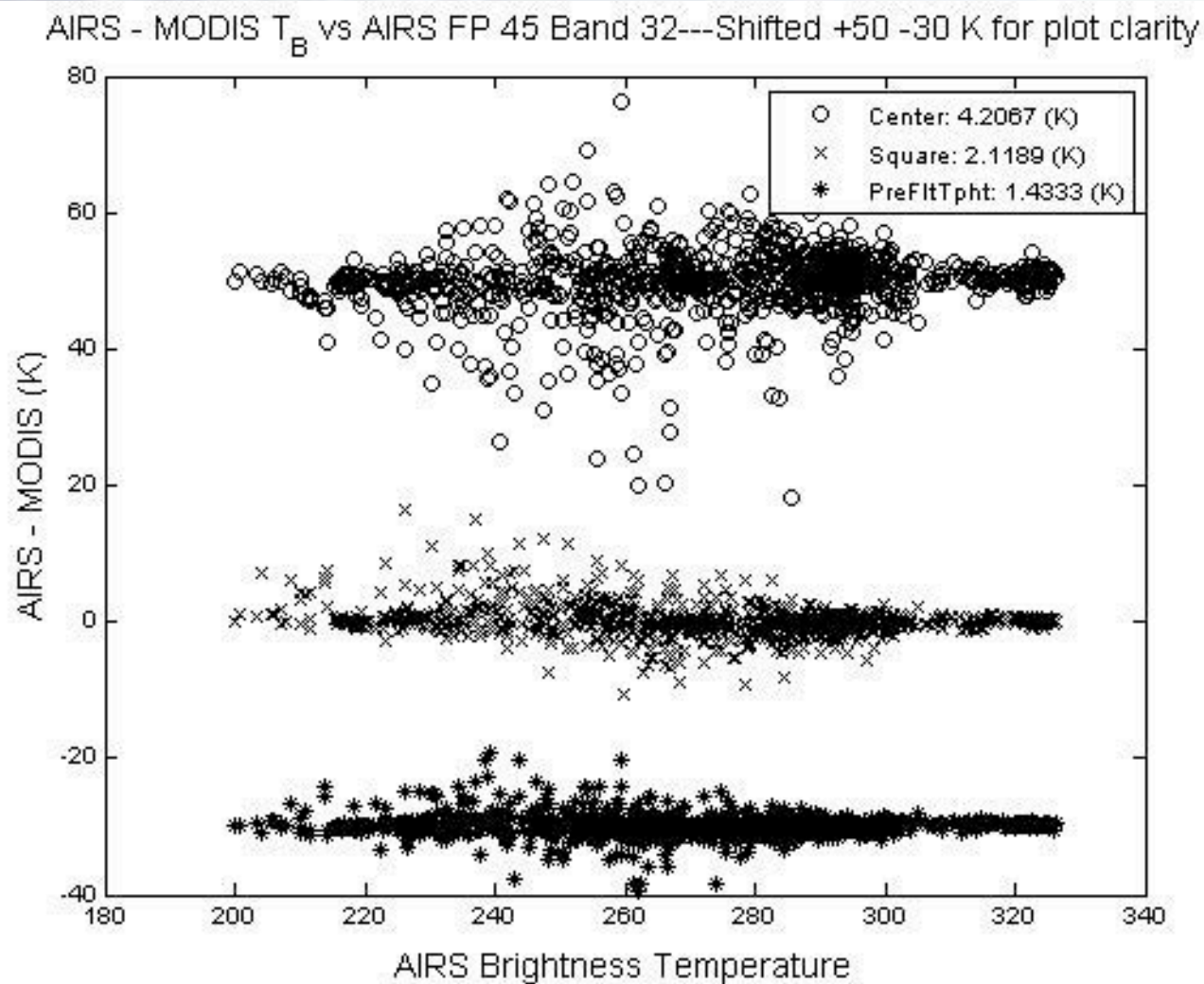


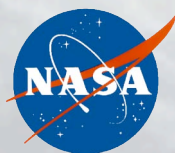
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AIRS - MODIS Band 32 FP45

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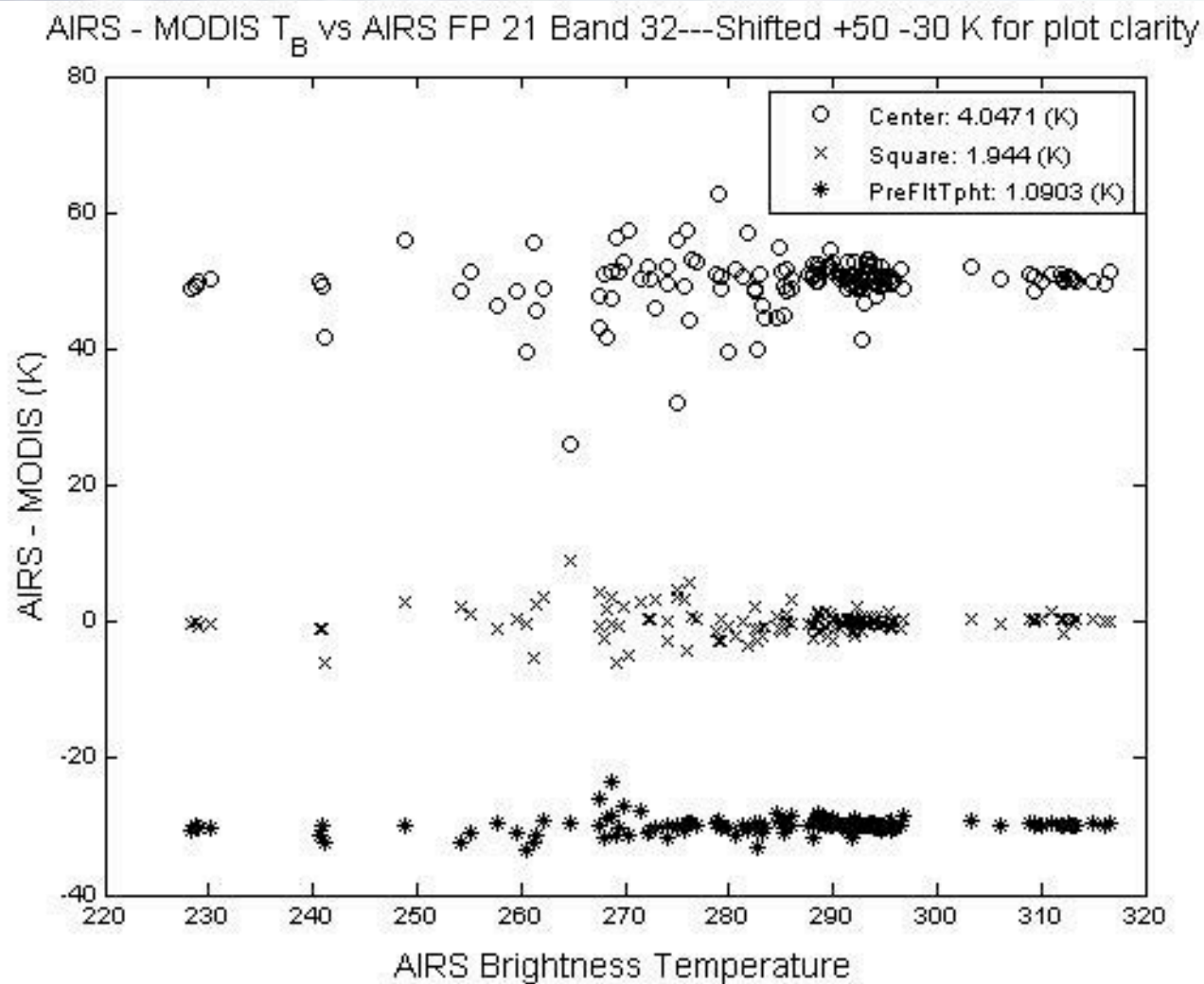


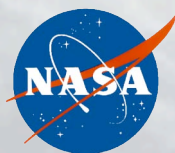
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AIRS - MODIS Band 32 FP21

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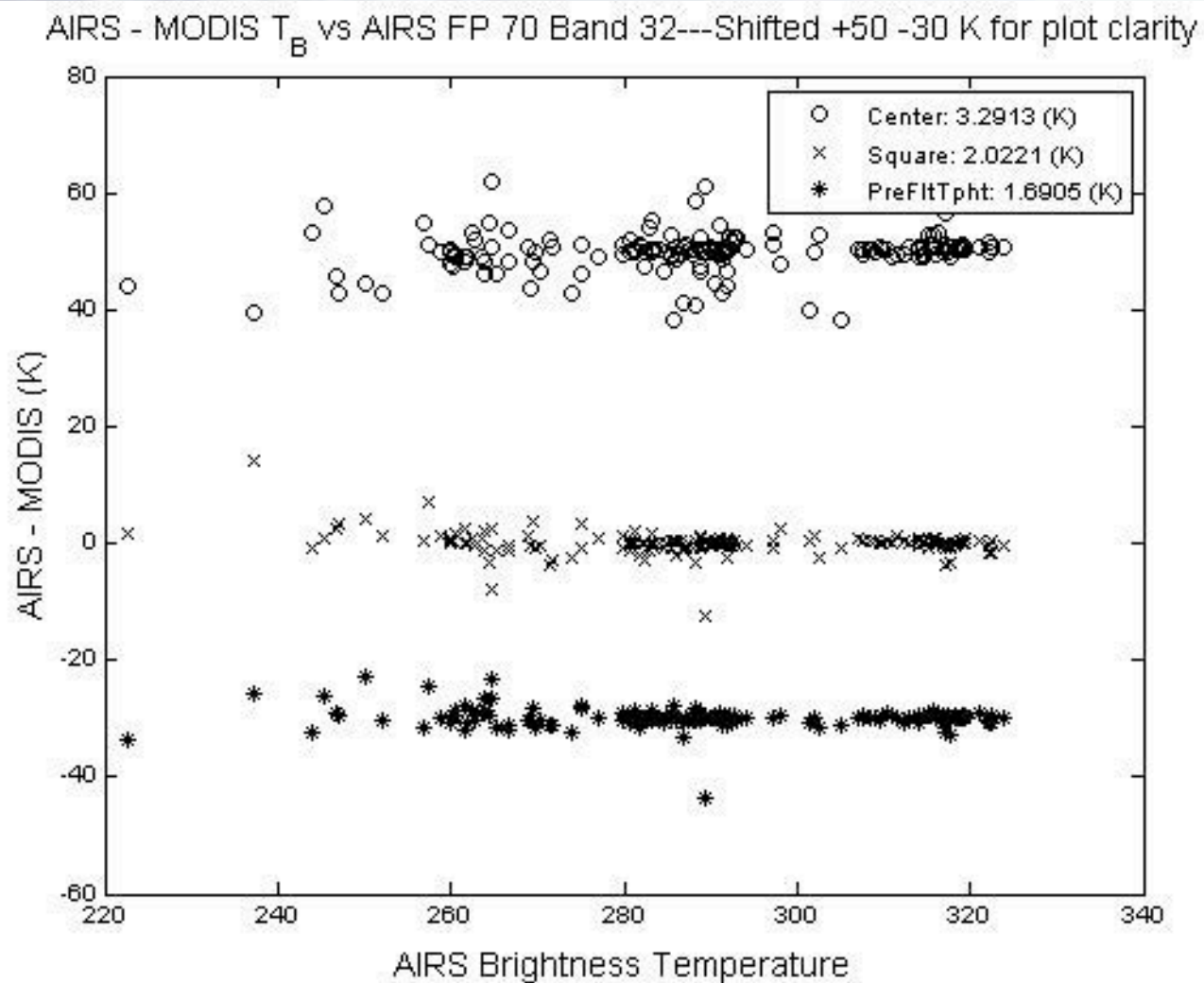


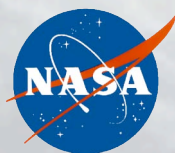
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AIRS - MODIS Band 32 FP70

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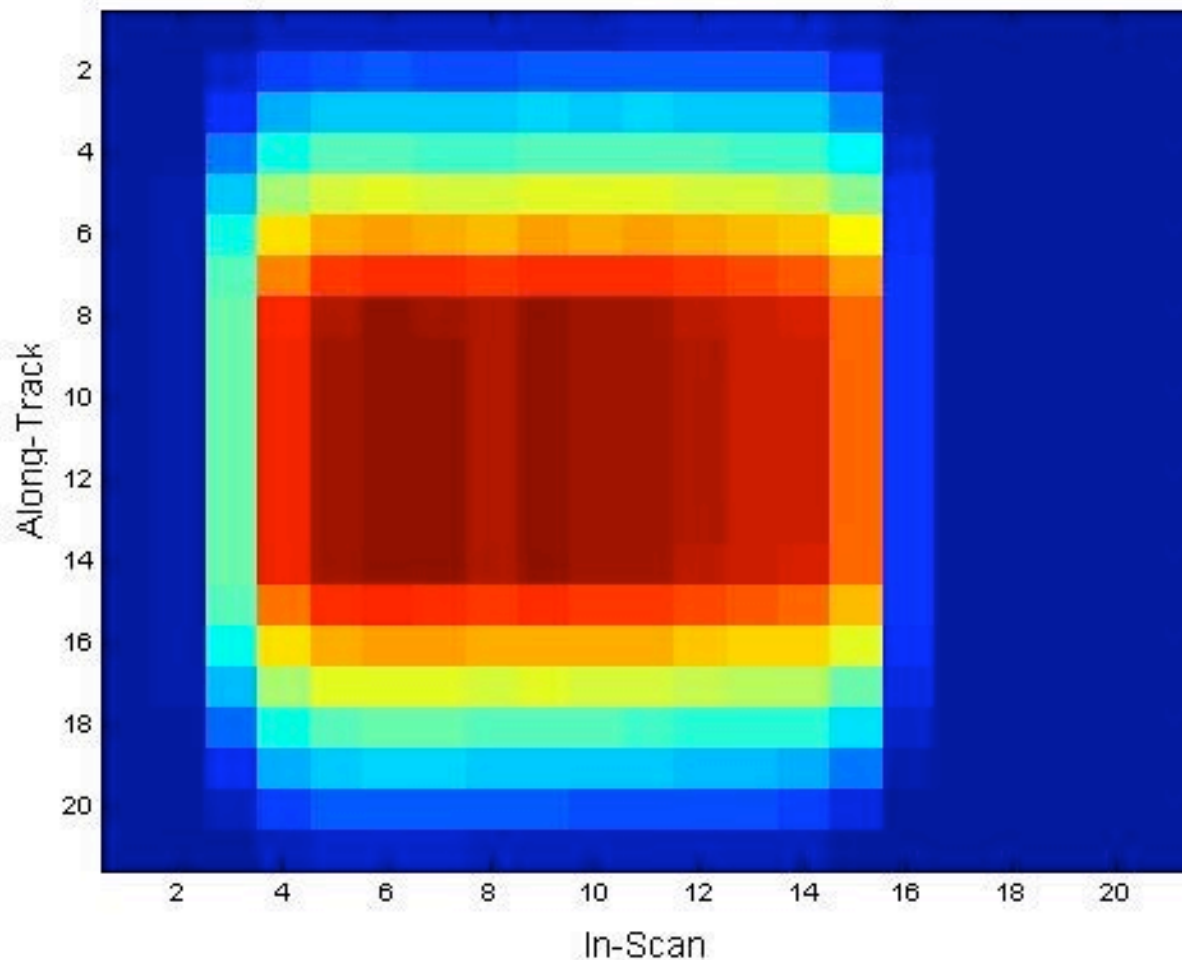
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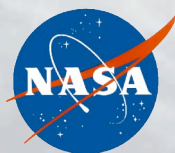
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AIRS Spatial Response at MODIS Resolution, Mean of Channels 518 and 540 FP 45

AIRS Spatial Response For Ch. 518 & 540 FP45 Resampled To MODIS Resolution





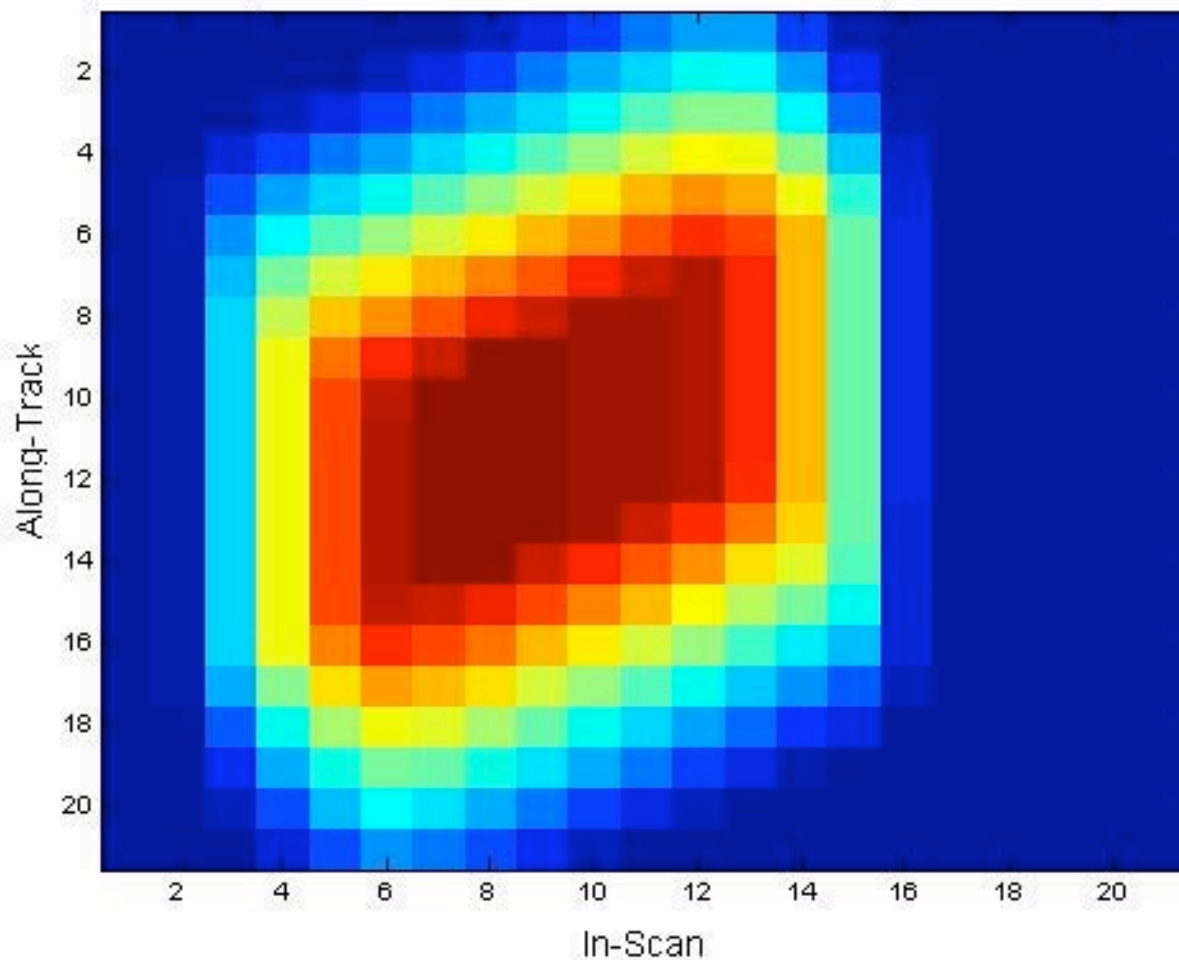
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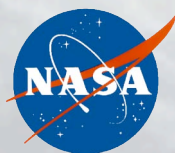
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AIRS Spatial Response at MODIS Resolution, Mean of Channels 518 and 540 FP 21

AIRS Spatial Response For Ch. 518 & 540 FP21 Resampled To MODIS Resolution





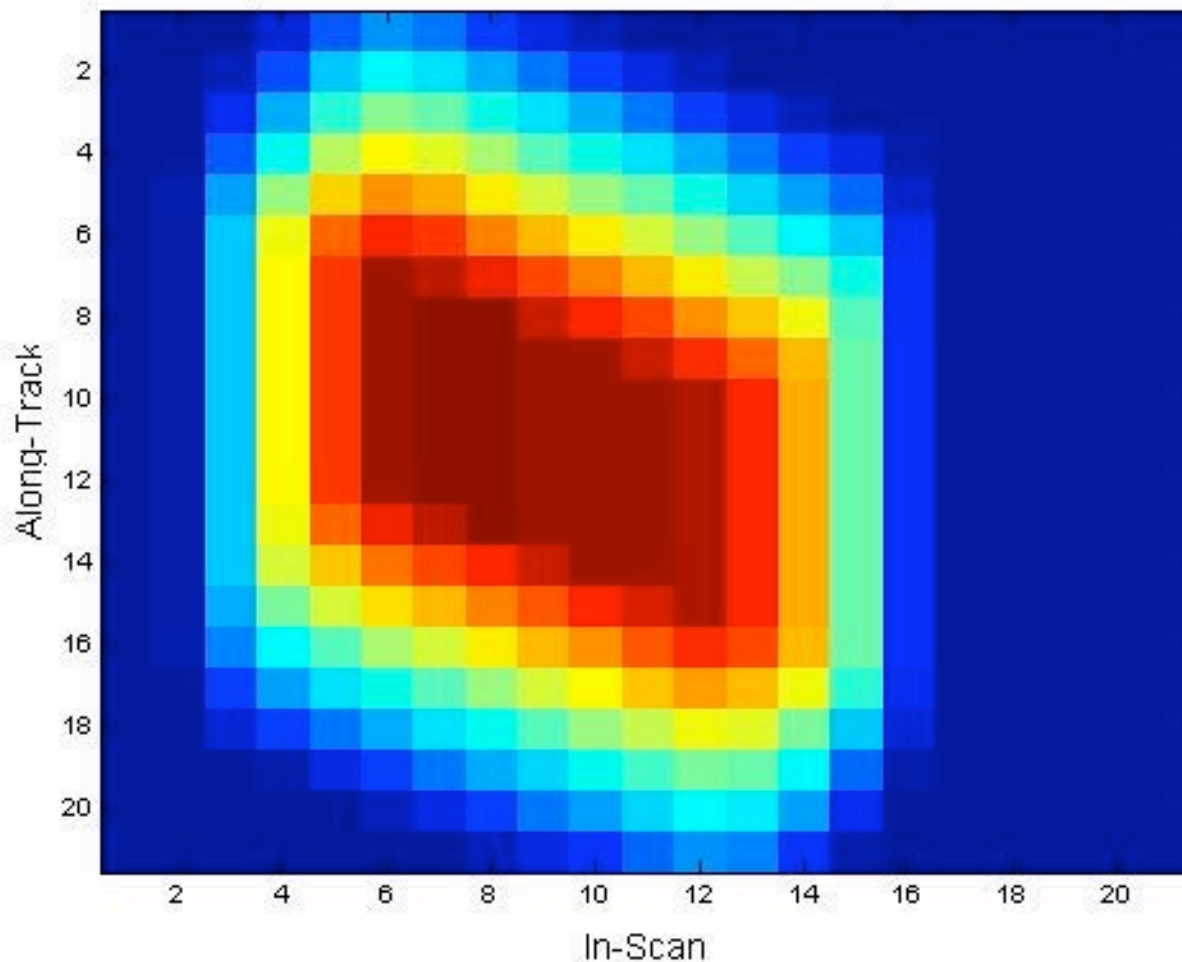
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AIRS Spatial Response at MODIS Resolution, Mean of Channels 518 and 540 FP 70

AIRS Spatial Response For Ch. 518 & 540 FP70 Resampled To MODIS Resolution





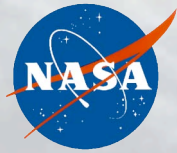
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Summary of Results

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MODIS Band	σ_{FP21}		σ_{FP45}		σ_{FP70}	
31	Nearest	3.99	Nearest	4.23	Nearest	3.41
	Mean	2.07	Mean	2.27	Mean	2.08
	Prod.	0.94	Prod.	0.57	Prod.	0.81
32	Nearest	4.05	Nearest	4.21	Nearest	3.29
	Mean	1.94	Mean	2.12	Mean	2.02
	Prod.	1.09	Prod.	1.43	Prod.	1.69



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Additional Checks

- **An idealized spatial response function (uniform circle of diameter 1.1 degrees truncated, rotated, and smeared) performs better than the straight average of the 21 x 21 neighborhood, but not as well as the measured responses**
- **Deliberately using an incorrect footprint in the analysis (using footprint 70 spatial response with data collected at footprint 21) also results in poorer performance**



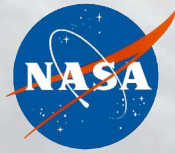
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Summary And Conclusions

- The pre-launch spatial response functions have been shown to improve comparisons between MODIS and AIRS radiometry in the two MODIS bands tested so far (31 and 32), significantly reducing scatter in typical scenes
- This partially validates the original pre-flight spatial response function measurements made at LMIRIS (now BAE Systems)
- The results are generally more significant in Band 31 than in Band 32
 - *The AIRS detectors used for the Band 31 comparison have less symmetrical spatial response functions than those used for the Band 32*
 - *So ignoring their shape introduces a larger error*



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Atmospheric Infrared Sounder

Calculating AIRS SRF's From Flight Data

- Another area of current work is an attempt to calculate the AIRS spatial responses from flight data alone
- The basic assumption, again, is that an AIRS image is equal to a MODIS image convolved with the AIRS spatial response function
- So far we have used both Fourier transform and matrix inversion techniques to solve for the AIRS spatial response, but without any good results
- Simulations work (we are able to reproduce what we put in after transforming in both directions)—but real data produces very poor results